aSpace Weather Technical Forecast

Issued on Sunday, 24 December 2023 at 12:33 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of M-class flares throughout. Chance of Minor Solar Radiation Storm S1 in near-term.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as recorded by GOES16, rose to Moderate levels in the past 24 hours. While the X-ray trace was largely flat with occasional small C-class flares observed, this abruptly ended with a late peak M2.9 observed at 24/1118UTC from sunspot region AR3529, an Eho/Beta. It is not yet clear from the time of writing as to whether any CME was produced, with imagery awaited.

There remain eight numbered sunspot regions on the Earth-facing side. The main changes in the period were seen in the northeastern quadrant, with strong recent growth in AR3530, which now shows as a Dri/Beta-Gamma. Also growing was a group to its east, AR3533, although this had a nominally simpler bipolar magnetic configuration and more gradual spot proliferation. All other groups were apparently stable or in decay.

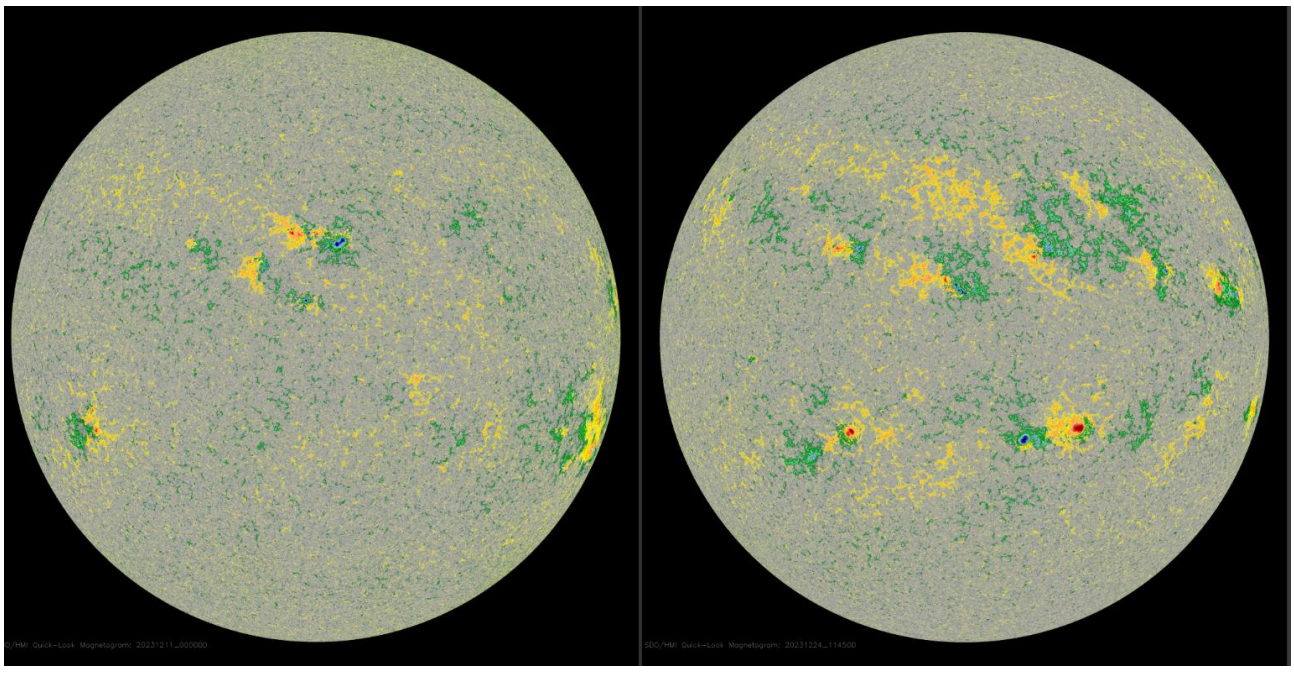

Figure 0: Rough view of the far hemisphere (pictured on 10 December when facing Earth), and the current facing side (24 December, 1145UTC), showing a strong difference in the strength of polarisation. So far this has not had a large impact on flare activity, and the filaments that occupy the current boundaries appear mainly stable – perhaps due to the lack of larger flares from active regions.

HMIBC imagery remains relatively starkly polarised at present, which is proving a fertile breeding ground for filaments on the boundaries of these areas. Two of these were relatively mobile over the

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24 hours - mainly the large filament near 35 West. A very faint and narrow Coronal Mass Ejection (CME), was perhaps associated with a period of disturbance in this feature peaking at 24/0130UTC, with part of the southern end perhaps the cause of the CME seen heading apparently south-poleward below the Sun-Earth line. Analysis of this will be conducted in due course, however it is felt most likely to be near a similar trajectory to the CME 24 hours earlier from a similar location - passing sufficiently below the ecliptic to not affect Earth. A second, slower lift-off then occurred on the northwest of the disc around 24/1100UTC. Coronagraph imagery for this event is not yet available but is now the main source of monitoring. At the time of writing, no definitively Earth-directed CMEs were in evidence.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by ACE and DSCOVR at L1, initially showed a disturbed slow solar wind regime, perhaps polluted by a minor transient, but gave way to a probable minor fast wind after 23/1600UTC. The source of this fast wind is uncertain given the positive phi angle (away from the Sun), with the only feature identified at a suitable solar longitude being CH83/-.

The solar wind speed was initially steady at 350km/s, but gradually rose after 23/1600UTC to eventually reach the low-400s of km/s into the current UTC morning. The solar wind density was near the long-term average in single figures ppcc throughout, with the observed peaks unreliable given the low numbers of particles involved and the discrepancy between ACE and DSCOVR's density measurements. The IMF was nominally at Background, but did show some structure, with a strongly anti-aligned Bz entering the 24 hours perhaps transient-related. The IMF was more erratic thereafter, with a very slight rising tendency to a peak of 8nT, with the absolute range of the north-south component +7 and -6nT.

The net result of the above solar wind measures was for provisionally Quiet to Unsettled geomagnetic activity, peaking with a Kp '3o' in the 00-03UTC interval.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at Background levels. GOES16 high energy (greater than 2MeV) electron flux peaked at High levels before falling, with a peak of 1070pfu at 23/1535UTC. The 24-hour fluence tracked downwards over the period, remaining below Active throughout, with the 24/0001UTC observation being 4.05e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a roughly stable daily Chance of Moderate activity in the four-day period.

Solar Wind / Geomagnetic Activity: No Earth-directed CMEs feature in the forecast. Current slightly elevated solar winds should soon ease, with no further fast winds anticipated. Initially Unsettled geomagnetic activity should soon revert to Quiet.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is at Background levels. There is now an increased Slight Chance in the next 24 hours of passing S1, given the M2.9 from near 20 West. This risk should fade to background later in the four days. High energy electron flux is expected to show a decline, with a falling Slight Chance of Active 24-hour integrated fluence.

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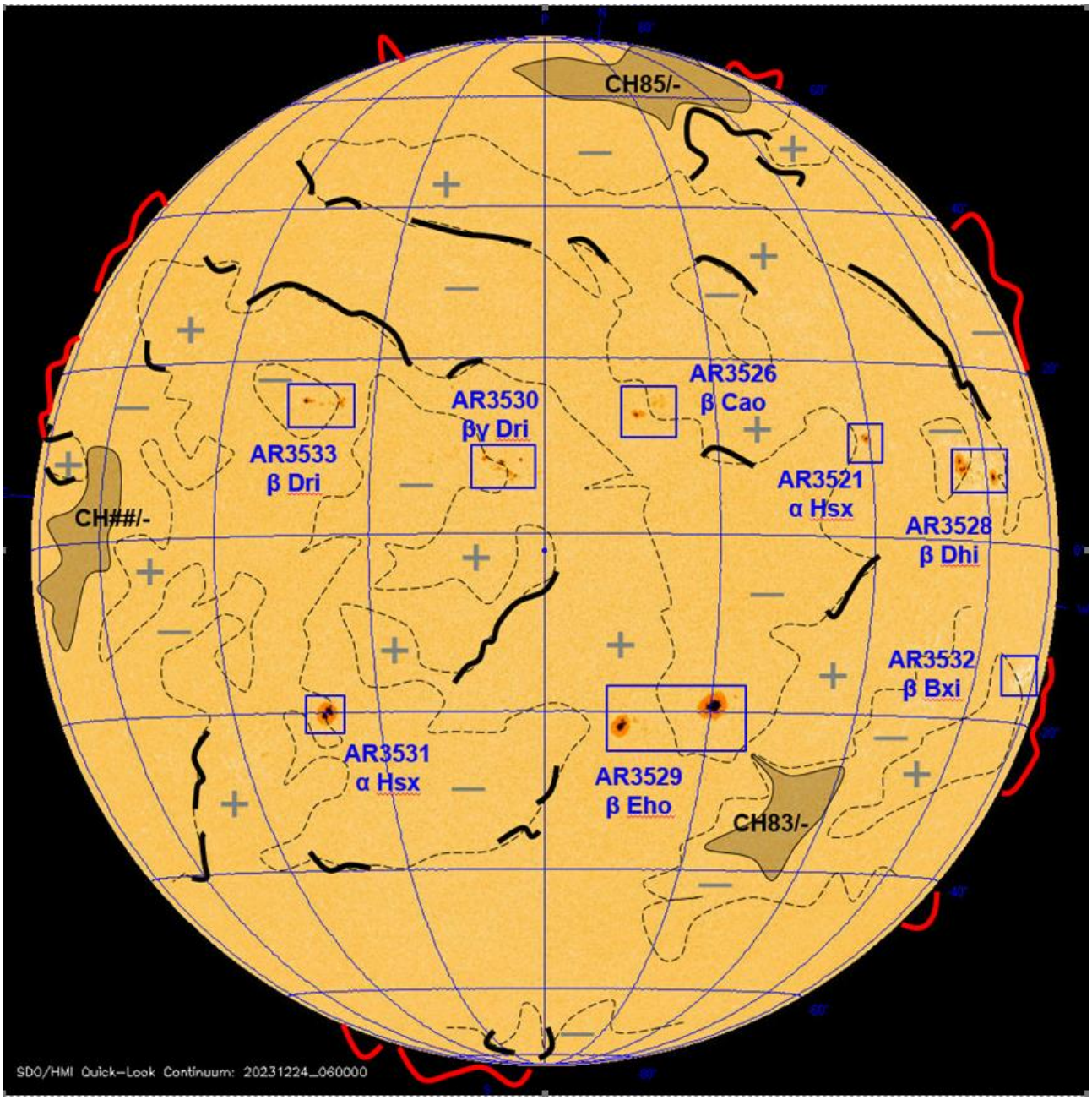
Figure 1. Solar Analysis Valid 24/0600UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

No Earth-directed CMEs currently feature in the forecast through the next four days.

Earth appears to be transiting a sector of space under the influence of a weak positive polarity fast wind as of 23/1600UTC. The only analysed coronal hole at roughly the correct solar longitude it CH83/-, and in more recent hours the near-north polar CH85/-, however both appear to be of incorrect polarity. The duration of this fast wind is therefore uncertain, but the solar wind speed appears to have plateaued, and it has likely now passed its peak geomagnetic activity.

No further fast winds are expected to feature, with MOSWOC Enlil's representation of a positive polarity 450km/s fast wind later on 27 December felt to be in error, with an ongoing slow regime preferred. Initially Unsettled intervals should soon fall to be largely Quiet through the Christmas period.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	1	1	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Nil.

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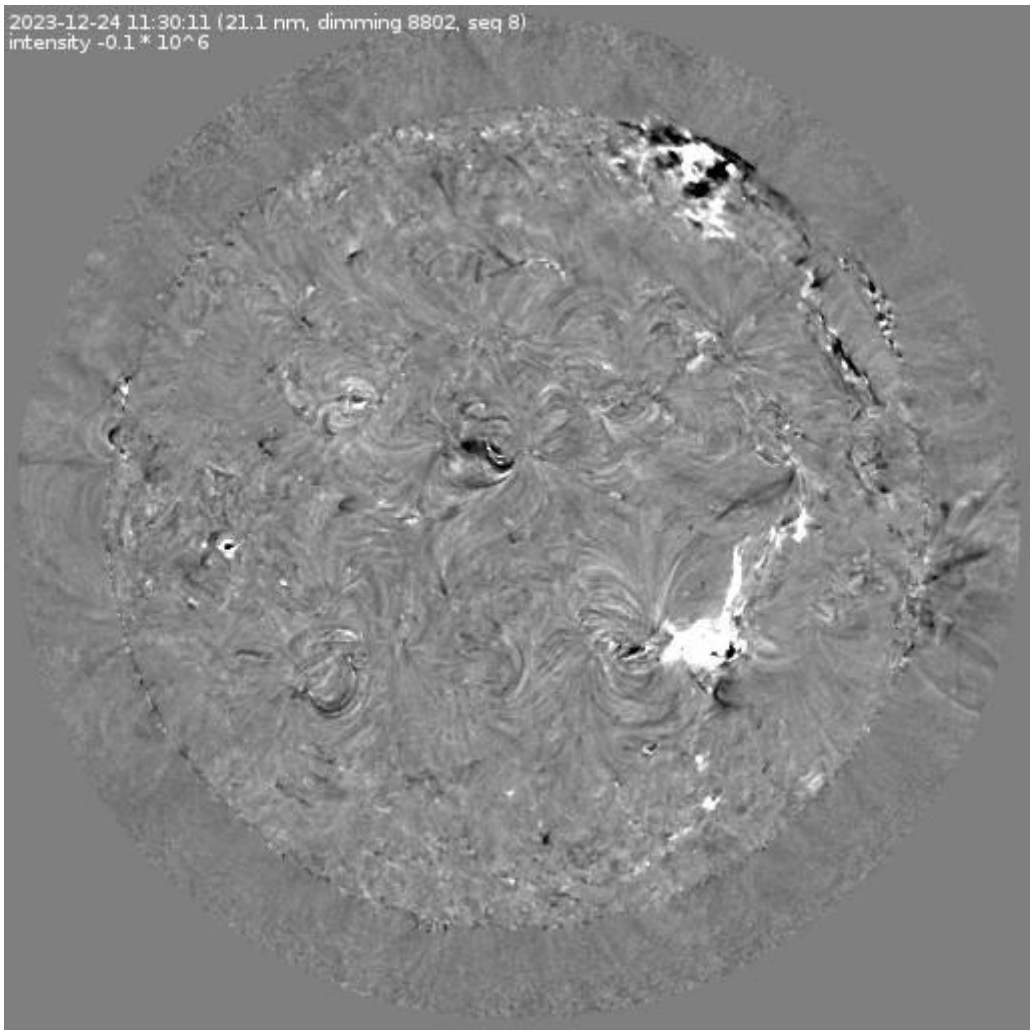
Figure 2: SIDC ROB-processed time integrated AIA 211 dimming, showing both the unstable filaments in the northwest and southwest at the time of the M2.9 flare. No CMEs were yet in evidence at the time of writing.



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Radio Blackouts - X-Ray Flares:

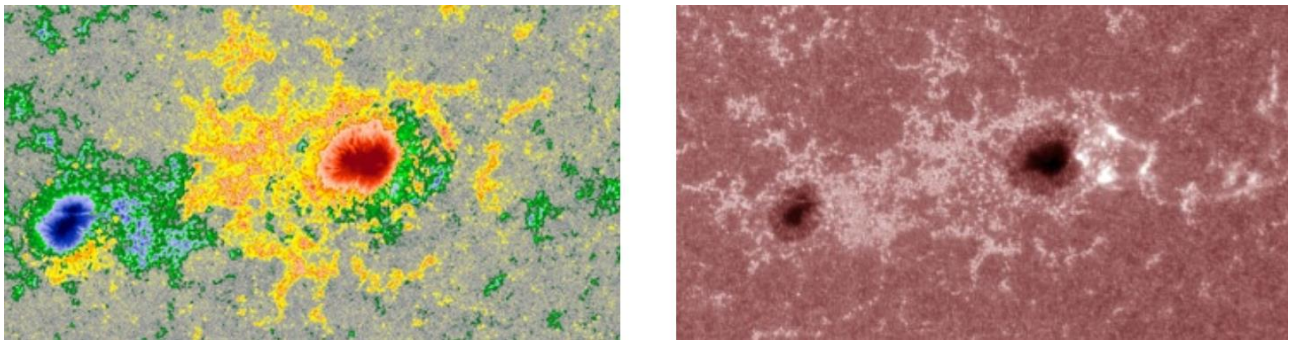
There are eight sunspot regions on the visible disc. Peak activity in the past 24 hours came from the only Zurich E-group on the disc, although this was somewhat against the run of play, as this group had appeared to be a simplifying mature and magnetically open group. The eventual M-class flare was perhaps associated with a partial halo of minor sunspots developing around the symmetric penumbral leader in the current UTC morning. This group excepted, the remainder of the disc potentially carries some potency with many Zurich D-groups, however this has so far not borne out in activity, with isolated low C-class flares observed from remaining regions.

There is expected to be little impact from individual regions rotating off the western limb in the period, with the only M class-producing region likely to be present throughout, and with all departing regions being quiet and well-spaced to ensure this happens gradually. Far-side soundings suggest that there are some potential sunspot containing plage regions due over the next 48 hours or so, roughly between Carrington 240-210. The westernmost part of this is perhaps now responsible for emerging flux looping over the northeastern limb. Recent far side eastern limb CME activity has been muted, and any increase in risk is therefore withheld until the regions present for analysis.

All considered, there is a constant Chance of M-class activity throughout.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: HMIBC and AIA1700 imagery at the time of the peak X-ray flare, showing the vicinity of the leader of AR3529 as being responsible (bright flux to right of main spot, right image), which appears to link to the observed unstable filament near 35 West. It is not yet clear as to whether any CME resulted, with imagery awaited.



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 has been at Background levels, however the M2.9 carries a historically-derived 15% Slight Chance of producing a solar radiation storm in excess of S1 from 20 West given its proximity to the issue time of this document. This gives a peak risk for the period in the coming 24 hours or so, with the risk relaxing to background in the absence of any further suitable flares.

The risk then relaxes to a residual Slight Chance of minor solar radiation storms through Christmas, with last week's most active region (Ex-AR3519) around a day over the western limb. As any risk from this group wanes, a succession of modestly complex sunspot groups should then rotate into the suitable positions to prolong the risk near the western limb through to the end of the forecast period.

Radiation Storms Probability (Exceedance)	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC) (%)**	**Day 2 (00-24 UTC) (%)**	**Day 3 (00-24 UTC) (%)**	**Day 4 (00-24 UTC) (%)**
Active	**≥ S1**	No	20	15	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has shown recent attenuation at GEO in light of geomagnetic activity from the unexpected minor fast wind enhancement from a positive polarity coronal hole. While unexpected and therefore of uncertain duration, it now appears to have peaked in potency. The currently observed low-400s of km/s fast wind is not likely to be capable of populating the Van Allen belts to breach the Active fluence threshold - especially given CH82/- failed to do so with a stronger and longer-lasting 500km/s fast wind.

The initial Slight Chance of Active fluence should therefore fall in the near-term, with the eventual rise over the Christmas period probably peaking at Moderate flux.

GEO Electron Environment Probability (Exceedance)	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC) (%)**	**Day 2 (00-24 UTC) (%)**	**Day 3 (00-24 UTC) (%)**	**Day 4 (00-24 UTC) (%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	5	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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